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SHIPROCK, NEW MEXICO URANIUM MILL ACCIDENT OF AUGUST 22, 1960

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16. Abstracts

The Shiprock, New Mexico, uranium mill accident of August 22, 1960, in which a raffinate waste liquor holding pond wall ruptured, is described. The conduct of field investigations of the incident are reviewed along with its effect on downstream water users. Chemical and physical data for river water samples leave little doubt that the mill wastes reached the San Juan River in considerable quantity by the following day. The need for stringent prevention measures is discussed.

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FOREWORD

This study was conducted and/or coordinated by each of the following: the U. S. Public Health Service Offices of the Taft Sanitary Engineering Center in Cincinnati, Ohio, the Colorado River Basin Water Quality Control Project in Denver, Colorado, and Division of Radiological Health of Region VII, Dallas, Region VIII, Denver, and Washington Headquarters offices; the San Juan County Health Department of the State of New Mexico, Farmington, New Mexico, and the Atomic Energy Commission, Division of Compliance, Idaho Operations Office.

Laboratory analyses were performed by facilities of the Taft Sanitary Engineering Center and Colorado River Basin Water Quality Control Project.

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The U. S. Geological Survey, Water Resources Division, Santa Fe, New Mexico in providing preliminary flow records of the San Juan River for the time of spill.

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The San Juan County Health Department of the State of New Mexico for their assistance in sampling.

The U. S. Bureau of Mines Navajo Station Plant and Kerr-McGee Uranium Mill in providing assistance in the conduct of survey and important information relating to the uranium mill spill.

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Personnel from the USPHS Indian Health Service Hospital at Shiprock, New Mexico who contributed information regarding the mill accident and downstream effects.

Personnel from the USPHS Colorado River Basin Project and the Taft Sanitary Engineering Center who, although not recorded in this report, aided in the laboratory analyses and preparation of material contained herein.

SHIPROCK, NEW MEXICO URANIUM MILL ACCIDENT OF AUGUST 22, 1960

INTRODUCTION

On August 22, 1960, at approximately 11:30 p.m., a raffinate waste liquor holding pond wall ruptured at the Kerr-McGee Uranium Mill at Shiprock, New Mexico, releasing the contents of two of a series of ten ponds to a wash leading to the San Juan River. Mill personnel estimate that this release occurred from 11:30 p.m. to 1:30 a.m. August 23 (1,2). However, an observer from the U. S. Bureau of Mines Helium Plant noted that the San Juan River immediately downstream from the mill appeared milky at 7:00 p.m. on August 22. Another employee from the Helium Plant on the morning of August 23 noted large numbers of dead fish in the San Juan River approximately 5 miles downstream from Shiprock (1). At 4:00 p.m. on August 22, a U. S. Geological Survey employee noted that the river 3 miles downstream was clear and also noted a number of apparently healthy fish in a pool. The following day at 8:00 a.m. this same person reported "many" dead or dying fish at the same location (1).

The dike failure and release of pond contents to the San Juan River were not immediately reported to local, State, or Federal officials by the mill management. First reports of a fish kill appeared in the local press on August 28, about 5 days following the release (3). Many observations of dead fish were made beginning on August 23 as noted above. Following local press releases, the incident was reported to personnel at the Public Health Service Indian Health Hospital at Shiprock, then to the Dallas and Denver Region VII and VIII USPHS Regional Offices, and subsequently to the USPHS facilities of the Colorado River Basin Project and the Taft Sanitary Engineering Center in Cincinnati, the States of New Mexico and Utah, and to the Atomic Energy Commission's Division of Licensing and Regulation.

CONDUCT OF FIELD INVESTIGATIONS

Following notification of the spill, arrangements were made for field observation and sampling. A field study was conducted during the period August 31 to September 3, 1960 jointly by personnel from the Public Health Service offices of the Taft Sanitary Engineering Center in Cincinnati, Ohio and the Division of Radiological Health, Region VII, Dallas, the San Juan County Health Department of the State of New Mexico, and the Atomic Energy Commission, Division of Compliance, Idaho Operations Office.

During this survey various types of environmental samples were collected. These included water and bottom sediment samples from the San Juan River; mill waste discharges and ponded waste liquors; sediments from the mill effluent channels and flood wash to the San Juan River in the general mill area; treated water from downstream water plants and filter sands from these water plants. In addition, small aliquots of San Juan River water samples collected by the U. S. Geological Survey

were also obtained. The latter samples represented a period of collection ranging from several days before to several days after the accidental mill release.

First-hand reports were also gathered at the time of the survey from personnel of the Kerr-McGee uranium mill, U. S. Bureau of Mines Navajo Helium Plant, U. S. Geological Survey and several other local witnesses in the area.

Radioactivity analyses on collected samples were undertaken by the Colorado River Basin Project Laboratory at that time temporarily located at the Occupational Health Field Station in Salt Lake City, Utah, the Taft Sanitary Engineering Center in Cincinnati, Ohio and a private laboratory. Bio-assay analyses were perfomed by the Taft Sanitary Engineering Center. Inorganic chemical determinations were not made on these samples.

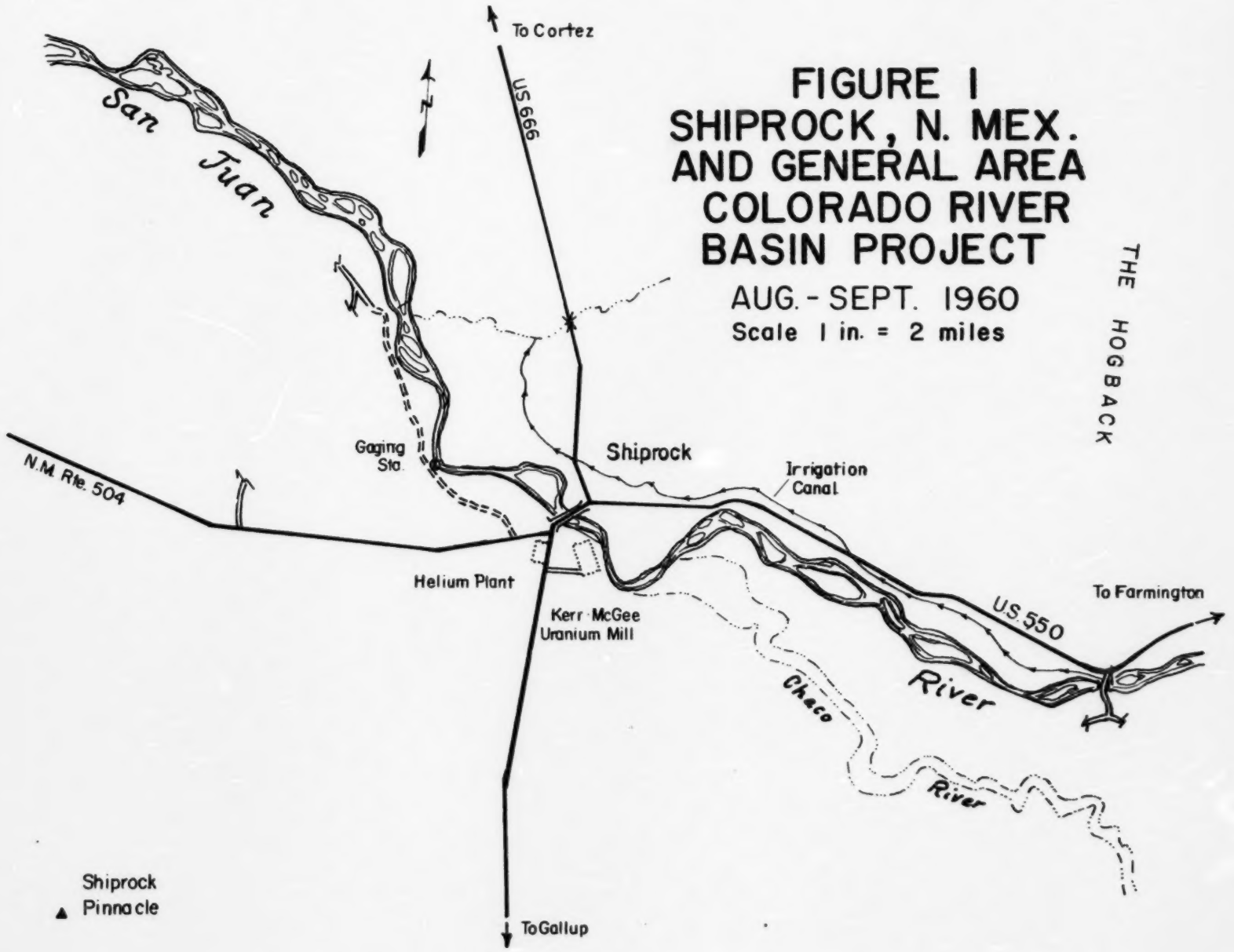
DOWNSTREAM WATER USERS

Several domestic water supplies are obtained from the San Juan River downstream of the Kerr-McGee uranium mill. The U. S. Bureau of Mines Navajo Helium Plant is located immediately below the mill and takes its water supply from three infiltration galleries in the river on the mill side 100 to 200 yards below the point at which the spill entered the river. Figure 1 presents a map of the Shiprock area, including the uranium mill location. A layout of the immediate area of the Kerr-McGee Uranium Mill is given by Figure 2. The Helium Plant water supply is filtered, softened by ziolite units, and chlorinated.

The water treatment plant and distribution system for the town of Shiprock, New Mexico is operated by the U. S. Bureau of Indian Affairs. Water is obtained from the San Juan River by means of an infiltration gallery located immediately below the uranium mill but on the opposite side of the river. This supply is supplemented at frequent intervals by water taken from an irrigation canal which diverts water from the San Juan River 9 miles above the town. Water plant personnel reported for the time of the Kerr-McGee spill, all water was obtained from the irrigation canal and not from the river infiltration galleries. This water supply is treated only by filtration (anthrafilt) and chlorination.

The only substantial demand of San Juan River water below Shiprock for domestic use is at Mexican Hat, Utah, 140 miles downstream of Shiprock. This water supply receives complete treatment by flocculation, settling, filtration, ion-exchange, and chlorination.

The town of Shiprock is on the Navajo Indian Reservation. The northern boundaries of the reservation are the Colorado-New Mexico border, and the San Juan River after the river leaves New Mexico. The San Juan River below Shiprock is used to some extent for irrigation of agricultural


To Cortez
US 666
San Juan
FIGURE 1
SHIPROCK, N. MEX.
AND GENERAL AREA
COLORADO RIVER
BASIN PROJECT
AUG. - SEPT. 1960
Scale 1 in. = 2 miles
THE HOGBACK
Gaging Sta.
Shiprock
Irrigation Canal
N.M. Rte. 504
Helium Plant
Kerr McGee Uranium Mill
US 550
To Farmington
Chaco River
Shiprock
Pinnacle
To Gallup

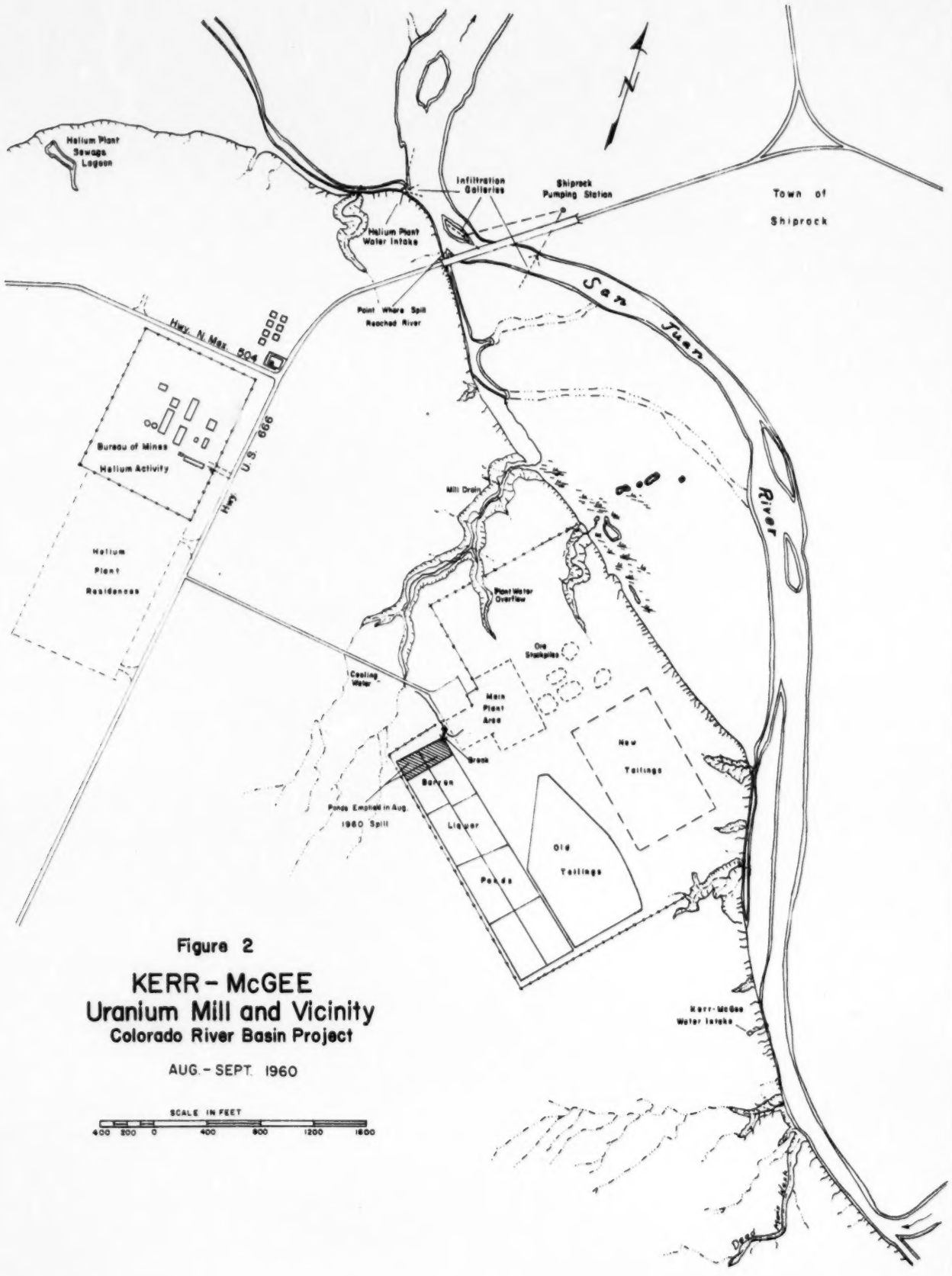


Figure 2

KERR - McGEE
Uranium Mill and Vicinity
Colorado River Basin Project

AUG. - SEPT. 1960

crops and it is also likely that river water without benefit of treatment, serves the domestic needs of many Indians. The number and location of such uses is variable and difficult to determine.

FIELD AND LABORATORY DETERMINATIONS

QUALITY AND QUANTITY OF WASTE RELEASED

An early estimate by the mill, the AEC, and USPHS of the volume of waste released was 250,000 gallons (1). However, the overall dimensions of the two ponds that were drained were approximately 120 feet by 350 feet. The average depth of the waste in the ponds before failure, as estimated by mill personnel, ranged from 1.5 to 2.5 feet. Based on the latter data, a revised estimate indicates that the released waste volume ranged from 470,000 to 780,000 gallons.

The accidental waste discharge was predominantly comprised of an organic raffinate, having an approximate pH of 1.7, and additionally contained kerosene, organic phosphoric acid, tributyl phosphate and other material.

Prior to completion of radium determination for samples collected on the mill site, Public Health Service personnel estimated that the total radium release during the spill was roughly 0.3 millicuries (1). Later results as obtained from the August 31-September 3, 1960 survey, showed that a liquid sample collected from a raffinate pond adjacent to the two in which failure occurred, contained 1200 μμc/l of Ra-226 (Table V). This sample raffinate liquor was very similar to that accidentally released on August 22-23, 1960. Using an average pond depth of 2.0 feet and a waste volume of 600,000 gallons, total radium released during the spill most probably was in the order of 2.8 millicuries.

CHEMICAL AND PHYSICAL DATA

Actual data for the time of the accidental release is scarce. However, certain information does exist and is given as follows:

pH

On the morning of August 23, Helium Plant personnel were contacted by Kerr-McGee uranium mill officials and alerted to watch the pH of their water supply. Observations by the Helium Plant indicated that the pH dropped from 7.8 to 7.4 but soon reverted to its original level (1).

Total Dissolved Solids and Specific Conductance

The total dissolved solids content of the Helium Plant raw water for the period corresponding to the accidental waste release is given in Table I. (1)

TABLE I
TOTAL DISSOLVED SOLIDS OF HELIUM PLANT RAW WATER

Date	Total Dissolved Solids (mg/l)
July 21, 1960	400
Aug. 23, 1960	1492
Aug. 24, 1960	2088
Aug. 25, 1960	2160
Aug. 26, 1960	2192

The U. S. Geological Survey collects samples of San Juan River water at the gaging station 3 miles below Shiprock on a routine basis for water quality determination. Conductivity data furnished by the U. S. Geological Survey for samples taken during the period August 19-23, 1960 at this location is shown in Table II (4).

TABLE II
CONDUCTIVITY OF SAN JUAN RIVER WATER IMMEDIATELY BELOW SHIPROCK

Date	Time	Spec. Cond. (μmhos)
August 19	7:30 p.m.	1940
" 20	6:30 p.m.	1940
" 21	12:05 p.m.	1820
" 22	11:15 a.m.	1860
" 23	8:00 a.m.	4390

Color

The U. S. Geological Survey in their collection of river water samples below Shiprock also noted that the sample obtained on August 22 (11:15 a.m.) was clear and uncolored whereas on August 23, the sample (8:00 a.m.) was orange-red in appearance. In addition on August 24, an observer at Mexican Hat, Utah noted a change in color of river water. However, as will be seen below, there is some evidence of rainfall occurring below Shiprock at this time and uncertainty exists as to the cause of the unusual color change observed at Mexican Hat (1).

When the above chemical and physical data are considered collectively, there is little doubt as to the presence of mill wastes in the river at and below Shiprock. The sharp rise in conductivity of river water samples collected by the U. S. Geological Survey with the change in pH of Helium Plant raw water on the morning of August 23, further strengthens the evidence that the mill spill reached the river in considerable quantity during the early hours of August 23, 1960.

RIVER FLOWS AND RAINFALL

There was early speculation that a local shower may have caused a sudden rise and fall of the San Juan River at and below Shiprock with a resulting sudden increase in turbidity or otherwise a stranding of aquatic life leading to the fish kill described previously.

Accordingly, all available flow information for the U. S. Geological Survey gaging station 3 miles below Shiprock and local rainfall data were obtained. Mean daily flows for August 18-31, 1960[1/] are given in Table III and hourly flows during August 21-24[2/] are shown in Table IV.

TABLE III
SAN JUAN RIVER FLOWS AT SHIPROCK - AUGUST 18-31, 1960

Date	Flow (cfs)
August 18, 1960	77
19	86
20	79
21	72
22	86
23	84
24	260
25	270
26	290
27	295
28	205
29	181
30	141
31	104

These data clearly show a sudden rise and fall in river flow on the morning of August 23 although this fluctuation was probably minor in terms of a hydrograph. It will be noted that the flows of the San Juan River were extremely low during this period.

In relating to the mill spill, flow rise of early August 23 began about 5 hours after the estimated time of spill and it appears reasonable that nearly this amount of time was needed for the river flow to travel from the point of accidental waste release to the gaging station. Although there are many unknowns relating to the flow increase

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1/ Final flow data as obtained from published USGS Water Supply Paper 1713 - Surface Water Supply of the United States, 1960 - Part 9. Colorado River Basin.

2/ Preliminary flow data obtained from the USGS Santa Fe Office in September, 1960. This data has probably been adjusted in final analysis, but is sufficiently accurate for the purposes used in this report.

TABLE IV
SAN JUAN RIVER FLOWS AT SHIPROCK - AUGUST 21-24, 1960

Flow (cfs)

Time	Aug. 21	Aug. 22	Aug. 23	Aug. 24
1A	76.6	72.0	92.7	113.
2	76.6	74.3	92.7	181.
3	78.9	81.2	90.4	197.
4	76.6	85.8	88.1	209.
5	76.6	83.5	101.	217.
6	76.6	81.2	119.	217.
7	74.3	78.9	116.	221.
8	74.3	78.9	107.	221.
9	74.3	78.9	101.	225.
10	74.3	78.9	92.7	229.
11	72.0	78.9	88.1	233.
N	72.0	78.9	85.8	245.
1 P	72.0	78.9	83.5	265.
2	72.0	78.9	83.5	280.
3	69.5	81.2	76.6	295.
4	69.5	88.1	72.0	307.
5	69.5	95.0	69.5	319.
6	67.0	98.0	69.5	343.
7	67.0	95.0	72.0	355.
8	64.8	92.7	72.0	349.
9	67.0	92.7	72.0	337.
10	69.5	92.7	72.0	319.
11	72.0	92.7	69.5	313.
12	72.0	92.7	74.3	301.
Mean	72.3	84.6	85.9	262.

of early August 23 such as the duration and actual volume of waste spill, the degree of longitudinal mixing in the river and measurement error of individual flow readings, it very much appears that this increase in large part reflects the flow of mill wastes past the gaging station. However, other causes for this rise in the hydrograph should not be completely discounted. Runoff resulting from a local shower and/or irrigation releases may have produced the same effect. Also, the river flow records did indicate an increase larger than accounted for by the reported volume of spill.

There was also a general rise in San Juan River flows beginning on the morning of August 23 which was probably due to upstream irrigation water releases or rainfall.

Information on rainfall in the general area showed that the Helium Plant reported precipitation for August 22 but this amount was measured at less than 0.10 inches and this was the only rainfall in a week (1). A rain gage at Fruitland, New Mexico, located 15 miles upstream from Shiprock indicated no rainfall between August 1 and September 1, 1960. A heavy rain did occur on August 22 in the Sanostee area but not at Shiprock. Surface runoff from this rain may have entered the San Juan River approximately 1 mile above Shiprock via Chaco Wash (1)(See Figure 1). There is no definite information which can relate a flow in Chaco Wash to the flow increase noted on early August 23 at the gaging station below Shiprock.

The above information strongly indicates that neither excessive turbidity or sudden changes in flow of the San Juan River were primarily responsible for the fish kill observed as beginning on August 23.

EYE-WITNESS ACCOUNTS

As previously stated, many dead or dying fish were observed in the San Juan River at points 3 and 5 miles downstream from Shiprock on the morning of August 23. It was noted that catfish were attempting to surface and also gathering near the stream's edge in a probable effort to avoid the main flow. An eye-witness report of dead fish was also made on August 24 by a USPHS Indian Health Service official at Aneth, Utah, some 50 miles below Shiprock (1).

Since the mill accident was not officially reported and investigated until many days after the occurrence, dead fish that could be found were partially decayed and consumed by wildlife and hence were not used for assay analyses.

FISH TOXICITY TESTS

Samples of waste similar to that released in the spill were obtained on September 1 from a pond immediately adjoining the two that were ruptured on August 22. Mill personnel verified as for the case of radium comparison that these wastes were similar in chemical makeup. Bio-assay tests were undertaken on these samples.

The collected wastes were tested for their toxicity to fathead minnows and bluegills. Dilution water was prepared with characteristics similar to San Juan River water. These tests indicated that this raffinate waste was "highly toxic" to the fish. Its 24-hour TL_m (Median Tolerance Limit) was 0.41 percent. This means that a volume concentration of 0.41 percent of this waste in unpolluted water would result in the death of 50 percent of the fish present within 24 hours.

It was calculated with the river flow of 88 cfs that existed at the time of the spill, a waste flow in the neighborhood of 0.37 cfs would have provided a waste concentration in the river equal to the 24-hour TL_m for the test fish. The duration of waste discharge and exact quantity

that reached the river cannot be definitely established. As noted above, the quantity released was perhaps in the order of 600,000 gallons, part of which could have seeped into the soil before reaching the river. The duration of spill may have been as short as 2 hours estimated by mill personnel or considerably longer. The spill apparently had not completely passed the gaging station by 8:00 a.m. on August 23, according to the above chemical data.

If 600,000 gallons of waste flowed in the river in even increments over a 5-hour period (the latter duration suggested by the hydrograph) it would have amounted to 4.4 cfs or 12 times the flow which provided the TL_m noted above. Averaging the waste flow over any period of discharge of course, is fallacious. The dispersion pattern of waste discharge in the river was not known. Also there probably was an early surge of waste to the river, with the flow diminishing thereafter. There is little doubt that the TL_m was exceeded in the river.

In addition, a "safe" concentration at which fish will be protected and not die is estimated by various authorities to be, at most, one-third of the TL_m and the majority of experts agree that the "application factor" should be set as one-tenth to sustain continued reproduction and other life processes. In other words, with the 88 cfs existing in the river at the time of spill, the maximum waste flow that may have been tolerated, using an application factor of one-third, was 0.12 cfs. This flow was very greatly exceeded.

One other item of interest was gleaned from the bioassay tests. The deaths that occurred in these tests were all within the first 24 hours of exposure. To reiterate, fish that survived the first 24 hours survived for the full 96-hour test period, and probably would have lived much longer. The toxicity of the waste was, therefore, seen to be immediate and sharp.

RADIOACTIVITY

As noted previously, it was estimated that 2.8 millicuries of radium were released during the spill of August 22-23, 1960. If this discharge was distributed over a 5-hour period to an average river flow of 88 cfs and was well-mixed with river water, an average radium concentration of 62 μμc/l would have resulted. This was about 20 times the continuous lifetime exposure maximum permissible concentration as set by the International Committee on Radiation Protection (5,6) and also approximately 20 times the maximum level of the U. S. Public Health Service "Drinking Water Standards" (7). The very short duration of such exposure made it minor in terms of allowable exposure even though the standards were momentarily exceeded. The case of the Helium Plant water supply withdrawn from the mill side of the river was slightly more serious. Some part of the waste may have passed through the infiltration galleries and into the raw water intake. In the event infiltration did occur, the radium concentration in the Helium Plant water supply probably exceeded even the 62 μμc/l level for a brief time since the waste was not fully mixed with the total river water at this downstream point.

Radium and uranium concentrations for water samples collected during the August 31-September 3 survey are given in Table V. Gross radioactivity and radium results for sediments, water plant filter sands, mill pond sludges and other are presented in Table VI. The locations at which most of these samples were collected may be found in Figures 1 and 2. These data showed little radioactive pollution of the river and domestic water samples especially when compared with normal background levels of 0.0-0.3 μμc/l radium-226 generally found in river waters, (8,9) 0.8-1.6 μμc/g radium in sediments (10), and 0-20 μg/l uranium in river waters (11,12,13,14). It must however be emphasized that the only samples approximating the occurrence of the spill in the river were the U. S. Geological Survey samples. These were the collection of August 23 at Shiprock and possibly those of August 24-26 at Mexican Hat, Utah. The only river water samples with a radium concentration significantly higher than background was the August 20 sample at Mexican Hat, collected 2 days before the mill spill. During a 3-day period of August 25-28, at Mexican Hat, radium concentrations in river water approximated 0.6 μμc/l indicating that the spill material may have been distributed over a long stretch of the river as it progressed downstream. Radioactivity levels in river water approximating the calculated values to be expected were definitely not indicated by the samples collected during the August 31-September 3 field survey. It has already been stated that too few samples were taken as representative of the time of spill. Furthermore, many estimates based on the best available knowledge were used to arrive at the total amount of radium released. If any one of these estimates was in considerable error, this would greatly affect comparisons of radioactivity levels attempted above.

As shown in Table VI, the Shiprock water plant anthrafilt after backwashing had a somewhat high radium content of 4.2 μμc/g. Also, filter sand collected from the Mexican Hat water plant contained a relatively high radium level of 14.0 μμc/g.

The flood channel (Kerr-McGee Drain) samples were single grabs and it is difficult to develop firm conclusions on results from these samples. However, these data do suggest the following:

1. The gross alpha radioactivity of the flood channel sediments throughout most of the channel length was several orders of magnitude in excess of background level. Background was taken as 10 μμc/g;

2. The concentrations of radium-226 in most of the flood channel sediments exceeded the background level taken as 1.3 μμc/g, by at least two orders of magnitude;

3. The high radioactivity within the bed of the flood channel was not due to the raffinate spill alone. The latter observation is based on sediment samples collected from the cooling water channel whose radioactivity was comparable

TABLE V--DISSOLVED RADIOACTIVITY OF WATER SAMPLES
Shiprock-Mexican Hat Area
August 31 - September 3, 1960 Survey

Description	Date	Ra-226 (μμc/1)	Uranium (μg/1)
San Juan R. at Shiprock (USGS Station)	8-19-60	0.04	34
" "	8-21	.00	18
" "	8-22	.16	29
" "	8-23	.20	18
" "	8-24	.13	30
" "	8-26	.17	13
" "	8-27	.20	6.6
" "	8-28	.14	6.0
" "	8-29	.12	6.1
San Juan R. at Mexican Hat (USGS Station)	8-20-60	1.4	---
" "	8-21	0.2	---
" "	8-22	0.55	---
" "	8-23	0.52	---
" "	8-24	0.3	2.9
" "	8-25	0.56	---
" "	8-26	0.58	---
" "	8-27	0.58	---
" "	8-28	0.59	---
" "	8-29	0.1	---
" "	8-30	0.2	---
" "	9- 1	0.32	12
" "	9- 3	0.08	8.7
" "	9- 4	0.01	12
San Juan R. at Texas-Zinc Minerals Corp. intake at Mexican Hat	8-31-60	0.41	15
" "	9- 1	0.29	14
" "	9- 2	0.22	1.6
" "	9- 4	0.57	15
San Juan R. at Kerr-McGee Mill intake	9- 1-60	0.37	10
" below wash entry into main channel, above Helium Plant intake	8-31	0.85	58
Helium Plant raw water	8-26-60	0.09	43
" " " "	9- 1	0.07	40
" " treated water	8-26	0.00	52
" " " "	9- 1	0.15	43
Shiprock treated water	9-1,2-60	0.11	19
Mexican Hat culinary water, treated	8-31-60	0.35	5
Seep 400 yds above Kerr-McGee intake	9-1-60	0.91	140
K-M[1/] raffinate, pond next to one that broke	9-3	1200	---
K-M drain, process & cooling water	9-	3.7	730

1/ K-M = Kerr-McGee

TABLE VI - RADIOACTIVITY OF SOLID SAMPLES
Shiprock-Mexican Hat Area
August 31 - September 3, 1960 Survey

Description	Date	Gross Alpha (μμc/g)	Gross Beta (μμc/g)	Ra-226 (μμc/g)
San Juan R. sediment, 10 miles above mill	9-3-60			1.5
" " " " opposite mill drain 1/	9-1	11	38	1.6
" " " " 3 miles below mill	9-3			0.7
" " " " 16 miles below mill	9-2			0.7
" " " " 25 miles below mill	9-2			0.5
" " " " above Mexican Hat, Utah	8-31	7.1	--	1.3
Helium Plant, regenerated zeolite resin	9-1			0.0
Helium Plant, spent zeolite resin	9-1			0.2
Helium Plant, pressure-filter sand after backwashing	9-1			0.3
Shiprock water plant anthrafilt before backwashing	9-1			1.9
Shiprock water plant anthrafilt after backwashing	9-1			4.2
Mexican Hat, Texas-Zinc Co. water plant sand from south filter	8-31 or 9-1			14.0
Texas-Zinc Co., water plant clarifier sediment	8-31	11.9		3.6
" " " sand from north filter	9-1			1.9
" " " suspended solids from 1 liter of treated culinary water	8-31			0.0
" " " suspended solids from 1 liter of water at intake	8-31			1.9

1/ Sample collected by AEC; reported analyses performed by US PHS.

TABLE VI - RADIOACTIVITY OF SOLID SAMPLES (Cont'd)
Shiprock-Mexican Hat Area
August 31 - September 3, 1960 Survey

Description	Date	Gross Alpha (μμc/g)	Gross Beta (μμc/g)	Ra-226 (μμc/g)
Kerr-McGee Holding Pond No. 1, top 1/2 inch of sludge[1,2]	9-1-60	577	775	32
Kerr-McGee Holding Pond No. 1, sludge at 2" depth[1]	9-1	1230	2100	106
Kerr-McGee Holding Pond No. 1, sludge at 6" depth[1]	9-1	304	344	30
Bank of flood channel arroyo - control[1]	9-1	9	45	2.1
Flood channel - 30 ft. west of break[1]	9-1	311	406	10
Flood channel - 40 ft. west of break[1]	9-1	44	166	≤ 1.0
Cooling water channel - 40 ft. west of break [1]	9-1	1290	1610	54
Kerr-McGee Drain[3] 200 ft. below break	9-1	----	----	8.7
" " " 500 ft. " "	9-1	----	----	2.6
Flood channel, 1/4 mile north of break [1]	9-1	95	158	6.8
" " 3/4 of distance from break to river bottom [1]	9-1	122	319	11.0
Kerr-McGee Drain floc, 2000 ft. below break	9-2	---	---	27
" " " mud, 2800 ft. below break	9-1	---	---	7.8
Flood channel at entrance to river bottom; upstream side [1]	9-1	361	374	---
" " " " " " " downstream side [1]	9-1	167	214	---
" " at west turn in river bottom [1]	9-1	638	496	23
Kerr-McGee Drain, 5100 ft. below break (at mouth)	9-3	---	---	1.7
Flood channel at confluence with San Juan R.[1]	9-1	27	42	1.4
Large semi-stagnant pool in river bottom [1]	9-1	91	206	4.9
Small pool adjacent to flood channel in river bottom[1]	9-1	179	245	---

1/ Sample collected by Atomic Energy Commission; reported analyses performed by US PHS.
2/ Pond emptied by dike break.
3/ Kerr-McGee Drain is same as flood channel below entrance of cooling water. Description varies according to the agency which collected the sample.

to that for sludge samples from the raffinate holding ponds. The cooling channel was thought to be carrying a relatively uncontaminated waste to the flood channel. The former may, however, have been contaminated by seepage from nearby raffinate ponds.

SUMMARY AND CONCLUSIONS

The rupture of a barren raffinate holding pond wall at the Kerr-McGee uranium mill at Shiprock, New Mexico, beginning during the night of August 22, 1960 released in the order of 600,000 gallons of highly-acid organic waste to the San Juan River. The break apparently resulted from poor compaction of the pond walls or because the ponds were filled beyond safe capacity, or both.

Chemical and physical data for river water samples leave little doubt that the mill wastes reached the San Juan River in considerable quantity during the early hours of August 23.

Various accounts established that large numbers of fish were killed in a reach of at least 50 miles of the San Juan River below Shiprock shortly after the spill. Evidence indicates that extreme chemical toxicity of the waste at the low river stage was, with very little doubt, the prime cause of the observed fish kills.

The maximum permissible concentration of the ICRP and the maximum level of the "Drinking Water Standards" for radium-226 were probably exceeded in the river water and Helium Plant water supply. However, this was limited in duration and of small consequence since these standards are based on continuous lifetime exposures. It is, therefore, extremely unlikely that any person suffered radiation over-exposure as a result of the Kerr-McGee uranium mill spill.

In view of the gravity of this accident and also that this type of incident has occurred elsewhere, it is highly necessary that uranium mills at the earliest possible time determine, and then initiate, practical measures to prevent such accidents in the future. Furthermore if a situation of this type does occur, it is imperative that the States affected, all downstream water users, and Public Health Service and Atomic Energy Commission officials be notified immediately.

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